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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : C23C 14/06, D21F 1/48, D21G 3/00	A1	(11) International Publication Number: WO 99/54520 (43) International Publication Date: 28 October 1999 (28.10.99)

(21) International Application Number: PCT/FI99/00316

(22) International Filing Date: 20 April 1999 (20.04.99)

(30) Priority Data:
980884 22 April 1998 (22.04.98) FI

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(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
With amended claims.
In English translation (filed in Finnish).

(54) Title: PARTS OF A PAPER/BOARD OR FINISHING MACHINE THAT ARE SUBJECTED TO INTENSIVE WEAR AND METHOD FOR MANUFACTURE OF SUCH PARTS

(57) Abstract

The invention concerns parts of a paper/board or finishing machine that are subjected to intensive wear when they are in contact with moving fabrics and with the paper web in a paper machine, as well as a method for manufacture of such wear parts or pieces. The part comprises a base material consisting of stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastics, thermoplastic resins, composite materials, and at least one wear-resistant PVD surface layer containing titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, or a diamond-like coating material, and that the form of the surface layer complies with the form of the underlying face.

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Parts of a paper/board or finishing machine that are subjected to intensive wear and method for manufacture of such parts

The invention concerns parts of a paper or board or finishing machine that are subjected to intensive wear when they are in contact with moving fabrics and with the paper web in a paper machine as well as a method for manufacture of such wearing parts or pieces.

In a paper or board or finishing machine, there is an abundance of parts or pieces which are worn very rapidly and become unusable because of the severe wearing conditions. Such pieces are typically, for example, water drain ribs in the wire part and in the press section, doctor blades, coating blades, and applicator bars used in surface sizing and in film coating applications. From applicator bars, excellent resistance to corrosion and hardness are required, and traditionally the bars have been made of a hard-chromium plated material, which is expensive and whose service life is limited. Usually, the surface of the bar is worn as it is rubbed against a roll coating or when there is a wearing paste which contains abrasive particles between the bar and the roll coating. The situation of wear is further affected by the fillers in the paper and by the impurities in the process. In general, good surface quality and good resistance to corrosion, low porosity, and high resistance to wear are required from the faces of doctor blades or coating blades. In a situation of wear, the face is worn and becomes chamfered, either when it is rubbed against a roll face or when, between the blade and the roll coating, a paste that contains abrasive particles, fillers in the paper and impurities in the process, such as quartz, abrade the blades. Traditionally, doctor blades or coating blades are made of a hard metal, plastic, or of a carbon-fibre reinforced or fibreglass-reinforced material. From the point of view of rapid wear, water drain ribs and other ribs in the wire part and in the press section in paper and board machines are also problematic. In applications of water drain ribs in a paper machine, the base face must be highly resistant

to corrosion, have small pores, and be resistant to wear. In a situation of wear, a fabric in the paper machine, such as a felt or a wire, runs across the face, which fabric includes abrasive minute particles, such as fillers of the paper and impurities from the process water. For the manufacture of water drain ribs, traditionally ceramic bits, sprayed ceramics, or hybrid structures which consist of combinations of different materials as well as electrolytic plating, such as hard-chromium plating, have been used. Compact ceramic ribs prepared by sintering are produced by gluing and/or mechanical joining together of smaller ceramic bits and by then gluing or mould-joining them onto a fibreglass-reinforced plastic rib. In stead of ribs with ceramic bits, a ceramic coating can also be prepared by thermal spraying. A problem is, however, the higher porosity of sprayed ceramic and in some cases also lower hardness. When sprayed ceramic materials are used, there is a risk of wear of the wires. Applications of use have, however, been found for thermally sprayed ribs in applications in which the machine speeds are lower, in which the rates of abrasion of plastic ribs are excessively high, and in which an embodiment with ceramic bits is again unduly expensive. However, with constantly increasing machine speeds, it is necessary to look for other applications. With ribs with ceramic bits, a what is called piano key effect occurs, in which the ceramic bits rise to different levels on the rib, which arises mainly from different thermal expansion coefficients of the ceramic bits and the support rib, from penetration of fillers of paper into the adhesive joints, and from the properties and strength of the adhesive in general.

PVD (Physical Vapour Deposition) technology has been used in high-speed steel tools for cutting machining, in moulds for plastics industry, in cores of moulds for pressure casting, and in tools and parts of manufacture in textile industry. The base material for a piece to be coated is typically hardened steel, high-speed steel, or sintered hard metal, whose hardness has been chosen so that it is suitable for the situation of wear in the conditions of operation, usually so that the components have a considerable service life even without coating. In such applications, the face placed under a PVD coating must be able to provide the thin PVD coatings with such a carrying layer that a particle that causes abrasive/erosive wear does not penetrate into the base material while splitting off the thin coating, or that, owing to

hardening, such mechanical properties are achieved for the material that the base material does not yield under the coating. In a PVD process, a thin, hard coating is formed out of a metal vapour from a source of coating and out of an ionized reactive gas used in the process, such as nitrogen, as the vapour and the gas are condensed on the face of the piece during simultaneous ion bombardment. PVD coating processes include, among other things, ion coating, magnetron sputtering, vacuum vaporization, and ion implantation, of which the first two are those that have been used most commonly. All of these processes are what is called vacuum coating processes. The magnetron sputtering process has been described in more detail, for example, in the patent publication *WO 91/14797*. The commonest PVD coating materials are titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, and diamond-like coatings (DLC).

The object of the present invention is parts or pieces of a paper or board machine that are subjected to intensive mechanical wear and a method for manufacture of such pieces in view of producing a highly wear-resistant coating which is as thin as possible and as economical as possible.

The parts and pieces in accordance with the invention for a paper/board or finishing machine and the method for manufacture of such pieces are characterized in what is stated in the patent claims.

It has been noticed that the problems that occur in connection with the prior-art solutions can be solved by using the PVD coating technology for manufacture of parts and pieces of a paper/board machine that are subjected to wear. In the solution in accordance with the invention, as the base material, it is possible to use a corrosion-proof material, stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastic or thermoplastic resin, or a composite material, which material has an adequate rigidity in its application of use. Further, if necessary, it must be reasonably possible to machine the base or bottom material to the shape of the desired object. Onto the base material, a sufficiently thick intermediate layer or carrying layer is prepared or coated in order that a particle that causes abrasive

and/or erosive wear should not be able to penetrate into the base material and to split off the coating. The carrying layer is typically prepared either electrolytically by hard-chromium plating or auto-catalytically by means of chemical nickel. The carrying layer may also have properties protecting from corrosion. In applications in which the hardness of the base material is sufficient, the carrying layer is optional and can be omitted. When the base material is soft, for example a reinforced or non-reinforced polymer material, a carrying layer is also needed to provide a homogeneous adhesion base so as to obtain a uniform final result and to protect the base material from possible damage. Onto the carrying layer, in some cases directly onto the base layer, a very hard, wear-resistant face is prepared by means of a PVD process. By means of the PVD process, a hard, low-friction coating is applied onto the face of the piece. The coating material can be, for example, titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, or a coating with low friction, such as a tungsten carbide/carbon coating, or a diamond-like (DLC) coating, or multi-layer coatings of those mentioned above. A very hard coating is prepared advantageously by means of a magnetron sputtering process. There can also be several coatings prepared with the PVD process one above the other, made of the same material or of different materials. In respect of its properties, a coating prepared by means of the PVD process differs clearly from a corresponding thermally sprayed coating, which is clearly more porous, thicker, and of inhomogeneous thickness. Also, a thermally sprayed coating must always still be machined after coating.

The hardness of the base material of the piece can vary in a range 180...230 HV. The hardness of the carrying layer may vary in a range 800...1000 HV, and the thickness of the carrying layer may vary in a range 10...100 μm. The hardness of the PVD coating, i.e. of the ultra-hard coating, may vary in a range 2000...3000 HV, and its thickness may vary in a range 0.5...25 μm. With diamond-like coatings (DLC), it is possible to achieve hardness levels of up to 6000...10000 HV.

The advantages of the solution in accordance with the present invention include low cost of production in the process, because the whole piece does not have to be made

of an expensive material of special hardness, but a less expensive material can be used as the base material, and a hard and durable coating is applied onto the base material. Also the cost of the hard-chromium plating and auto-catalytic coating needed in the carrying layer is relatively low, and suitable applications are abundantly available. With a PVD process, the thickness of the coating is uniform all over, so that, in the case of a coating or of a multi-layer coating, the shape of the surface of the coated piece complies with the shape of the face placed under the outermost coating layer. In order that the desired properties of resistance to wear of the piece should be retained, the piece is coated by means of a PVD process over its entire operational area of wear. If it is desirable to regulate the wear in a controlled way, it is possible to use coatings with different levels of hardness at different locations on the piece. A PVD-coated piece does not require mechanical working, machining, or finishing, but it is as such ready for use after the coating. At present, PVD coating equipments also suitable for larger pieces are already available.

In the following, three preferred solutions in accordance with the present invention will be examined in more detail by way of example, the invention being, however, not supposed to be confined to said solutions alone.

Applicator bars in a paper or board machine

The wear-resistant solution in accordance with the invention can be applied favourably to the manufacture of applicator bars, which bars are used, for example, in surface sizing and film coating applications in **SymSizer** and **SymCoat** equipments (Valmet Corporation). In stead of a conventional hard-chromium plated bar, out of a base material of stainless or acid-proof steel, a smooth or grooved bar is manufactured by means of conventional methods, an electrolytic or auto-catalytic coating is applied as a carrying layer onto the bar, and as a typical example of the former coating can be mentioned hard-chromium plating, and of the latter coating, chemical nickel. Onto the carrying layer, out of an ultra-hard PVD coating, such as, for example, titanium nitride or titanium aluminonitride or multi-layer coatings of the above or out of diamond-like coatings, or out of any other coating produced by

means of a PVD process, a hard and low-friction coating is prepared. In order to achieve the resistance to corrosion necessary for applicator bars, as the base material it is necessary to use stainless steels, whose basic hardness is low and which do not provide an adequate hardness and a carrying layer for the thin hard coating. This is why a sufficiently thick, typically 10...100 μm thick, carrying layer is applied onto the stainless steel. Onto this carrying layer, an ultra-hard wear-resistant layer is applied by means of a PVD process, preferably magnetron sputtering. From the face of an applicator bar, as a rule, good surface quality, resistance to corrosion, low porosity, and high resistance to wear are required. These properties are, however, not required throughout the entire thickness of the material, but from the surface layer only. As compared, for example, with ceramic bars, the advantages of the applicator bar in accordance with the present invention include resistance of the coating to a thermal shock, good adhesion of the coating to the base material, and stability of the tolerances of the base material as the measures are not changed to a substantial extent because of the thin coating, which is an important advantage in particular in the manufacture of grooved bars. Further advantages include low friction coefficient and also low wear of the backup face, i.e. of the roll face. The thermal expansion coefficients of the materials are compatible with each other, the solution provides a possibility for free design of the face, the face is not porous, as a ceramic face would be, the surface quality is excellent both on smooth bars and on grooved bars, the face endures mechanical impacts considerably better than a ceramic face does, the bar does not damage the roll coating, in the coating it is also possible to use coatings of low surface energy, such as molybdenum sulphide, if the surface layer of the bar has been worn to a reasonable extent, the material can be coated again, and since the coating temperature can be kept low, even lower than 100 °C, the resistance to corrosion of the base material is not changed or deteriorated, nor is the straight form of the base material changed.

Doctor blades and coating blades

The solution in accordance with the invention can also be used favourably in a low-friction doctor blade or coating blade for a paper or board machine. Traditionally,

the blades have been manufactured out of a hard metal, plastic, or out of a rib reinforced with carbon fibre or with fibreglass. As the base material of a doctor blade or coating blade, it is possible to use a metal, a composite, or a carbon-fibre or fibreglass reinforcement. If the base material is sufficiently hard, no carrying layer is needed in between; when softer base materials are used, a carrying layer is applied onto the face, the thickness of said carrying layer being 10...100 μm, preferably 50 μm. Onto the carrying layer, a wear-resistant ultra-hard PVD coating is applied, preferably by means of the magnetron sputtering method, and the coating is applied preferably to the wear area of the blade. By means of the PVD coating, the blade is provided with good surface quality, good adhesion, low friction coefficient, high hardness, and suitability also for faces of highly complicated cross-section. In this way a doctor blade or a coating blade is obtained which has very low friction and is highly resistant to wear. The coating endures a thermal shock well, as compared, for example, with a coating with a ceramic tip. The coating adheres to the base material well. The tolerances of the base material are stable, because, owing to the thin coating, the measures are not changed to a substantial extent and, thus, there is no need to finish the blade. The blade has a very low friction coefficient, and the wear of the backup face is also little. The thermal expansion coefficients of the coating and of the base material are compatible with each other. This solution permits free design of the face. Different chamfers can be coated, and no multi-stage grinding is needed, as is needed in the case of blades with ceramic tips. The face is not porous, as is the face of a ceramic, and the face endures mechanical impacts considerably better than a ceramic does. The blade does not damage the roll coating. This technique also permits the use of low-energy coatings, such as molybdenum sulphide. The doctor blades can also be coated again after they have been worn. The resistance to corrosion of the base material is not changed or deteriorated, because the coating temperature can be kept low, which is highly important, for example, in the case of steel, nor is the straight form of the base material changed out of this reason. The blades can be coated while winding them from one reel onto another in a vacuum chamber, in which case large vacuum chambers for coating are not needed. In such a case, the base material to be coated is unwound from a first reel and wound onto a second reel, while the coating takes place in the area between

the reels. Owing to the low coating temperature, it is also possible to coat blades with carbon-fibre and fibreglass reinforcements.

Water drain ribs in a wire part and in a dryer section

As a third exemplifying embodiment of the invention can be mentioned the water drain ribs in a wire part and in a press section. Traditionally, water drain ribs for wire parts and press sections have been manufactured out of plastic, sprayed ceramic, ceramic bits, metal, or out of combinations of same. In the solution in accordance with the invention, in view of achieving a resistance to corrosion of the water drain members, as the base material stainless steels are used, whose basic hardness is low. Onto the stainless steel, a sufficiently thick carrying layer, typically of a thickness of 10...100 μm, is coated either by hard-chromium plating or auto-catalytically, for example, with chemical nickel. Onto this carrying layer, an ultra-hard, wear-resistant face is prepared by means of a PVD process, preferably magnetron sputtering. In stead of a conventional rib which is hard throughout, onto the desired base material a carrying layer coating or a combination of coatings is applied, which has a hardness higher than the hardness of the base material, which base material is softer and can be worked readily, so that the surface layer of the blade can resist penetration of individual particles into the base material, the surface layer provides the PVD coating with a suitable adhesion base, the surface layer has a good surface quality, and the coating processes, including the coatings in the intermediate layer, do not change the measures of the rib to a substantial extent, and the surface layer has a low porosity and a low friction coefficient. The wear resistance proper is obtained with the PVD coating with which the intermediate layer is coated. Features typical of the PVD coating are good surface quality, good adhesion, low friction coefficient, very high hardness, and suitability for complex faces. The advantages of a PVD-coated water drain rib of a wire part or of a press section include excellent resistance of the coating to a thermal shock, good adhesion of the coating to the base material, stability of the tolerances of the base material as the measures are not changed to a substantial extent by the effect of the thin coating, low friction coefficient, low wear of the backup face, and the thermal expansion

coefficients of the materials can be made compatible with each other if the rib has been constructed out of different layers by means of mould joining. This permits free design of the shape of the face, the design does not impose obstacles on coating, the coating is not porous, the resistance to corrosion and the alloying of the base material can be selected in compliance with the particular application, the resistance to corrosion of the base material, i.e., for example, stainless steel, is not deteriorated, because the PVD coating temperature can be kept low, lower than 100 °C, the straight form of the base material is retained because of the low coating temperature. No adhesive joints are needed in the ribs, in which case fillers do not adhere to the ribs and cannot cause an abrading effect. A what is called piano key effect does not occur. In this way, an excellent surface quality is achieved, in particular if the base material is polished electrolytically before hard-chromium plating and if mechanical polishing is carried out after the chromium plating. In such a case, Ra values are achieved which are lower than 0.05 μm. The coating can be renewed by grinding and re-coating the rib.

Claims

1. A part of a paper/board or finishing machine that is subjected to wear, **characterized** in that the part comprises a base material consisting of stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastics, thermoplastic resins, composite materials, and at least one wear-resistant PVD surface layer containing titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, or a diamond-like coating material, and that the form of the surface layer complies with the form of the underlying face.

2. A part as claimed in claim 1, **characterized** in that, between the base material and the wear-resistant surface layer, the part comprises a carrying layer, which consists of a layer prepared by means of electrolytic hard-chromium plating or of a chemical nickel layer prepared auto-catalytically.

3. A part as claimed in claim 1 or 2, **characterized** in that the thickness of the carrying layer is 10...100 μm, and the thickness of the wear-resistant PVD surface layer is 0.5...25 μm.

4. A part as claimed in any of the claims 1 to 3, **characterized** in that there are at least two PVD surface layers, and said layers consist of the same material or of different materials.

5. A method for manufacture of parts of a paper/board or finishing machine that are subjected to wear, **characterized** in that, onto the base material that constitutes the part, at least one wear-resistant surface layer is applied by a PVD process.

6. A method as claimed in claim 5, **characterized** in that, onto the base material, a carrying layer is applied by means of electrolytic hard-chromium plating or auto-catalytically out of chemical nickel, and onto the carrying layer a wear-resistant PVD surface layer is applied.

7. A method as claimed in claim 5 or 6, **characterized** in that the thickness of the carrying layer is 10...100 μm, and the thickness of the PVD surface layer is 0.5...25 μm.

8. A method as claimed in any of the claims 5 to 7, **characterized** in that at least two PVD surface layers are applied, and said layers can consist of the same material or of different materials.

9. A method as claimed in any of the claims 5 to 8, **characterized** in that the part is made of a base material consisting of stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastics, thermoplastic resins, composite materials, and, onto the base material, at least one wear-resistant PVD surface layer is applied, which contains titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, or a diamond-like coating material.

10. A method as claimed in any of the claims 5 to 9, **characterized** in that the base material to be coated is unwound from a first reel and wound onto a second reel, while the coating takes place in the area between the reels.

11. A doctor blade or a coating blade for a paper/board or finishing machine, **characterized** in that the blade comprises a base material composed of hardened steel, high-speed steel, or of sintered hard metal, onto which base material a PVD coating has been applied.

12. A doctor blade or a coating blade as claimed in claim 11, **characterized** in that, between the base material and the PVD coating, there is a carrying layer, which has been prepared by means of electrolytic hard-chromium plating or auto-catalytically out of chemical nickel.

13. A water drain rib for the wire part or for the press section in a paper/board or finishing machine, **characterized** in that, onto a base material, which has been made of stainless steel or acid-proof stainless steel, a carrying layer has been prepared,

which is an electrolytic or auto-catalytic coating, and onto the carrying layer a PVD coating has been applied.

14. An applicator bar for a paper/board or finishing machine, **characterized** in that, on a base material made of stainless steel, there is a carrying layer which has been prepared electrolytically by hard-chromium plating or auto-catalytically, and on said carrying layer there is a PVD coating.

AMENDED CLAIMS

[received by the International Bureau on 23 August 1999 (23.08.99); original claims1-14 replaced by amended claims 1-12 (3 pages)]

1. A part of a paper/board or finishing machine that is subjected to wear, **characterized** in that the part comprises a base material consisting of stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastics, thermoplastic resins, composite materials, and at least one wear-resistant PVD surface layer containing titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, or a diamond-like coating material, that the form of the surface layer complies with the form of the underlying face, that between the base material and the wear-resistant surface layer, the part comprises a carrying layer, which consists of a layer prepared by means of electrolytic hard-chromium plating or of a chemical nickel layer prepared auto-catalytically, and that the thickness of the carrying layer is 10...100 μm, and the thickness of the wear-resistant PVD surface layer is 0.5...25 μm.

2. A part of a paper/board or finishing machine that is subjected to wear as claimed in claim 1, **characterized** in that there are at least two PVD surface layers, and said layers consist of the same material or of different materials.

3. A method for manufacture of parts of a paper/board or finishing machine that are subjected to wear, **characterized** in that, onto the base material that constitutes the part, at least one wear-resistant surface layer is applied by a PVD process.

4. A method as claimed in claim 3, **characterized** in that, onto the base material, a carrying layer is applied by means of electrolytic hard-chromium plating or auto-catalytically out of chemical nickel, and onto the carrying layer a wear-resistant PVD surface layer is applied.

5. A method as claimed in claim 3 or 4, **characterized** in that the thickness of the carrying layer is 10...100 μm, and the thickness of the PVD surface layer is 0.5...25 μm.

6. A method as claimed in any of the claims 3 to 5, **characterized** in that at least two PVD surface layers are applied, and said layers can consist of the same material or of different materials.

7. A method as claimed in any of the claims 3 to 6, **characterized** in that the part is made of a base material consisting of stainless steel, carbon steel, alloyed or non-alloyed steel, thermosetting plastics, thermoplastic resins, composite materials, and, onto the base material, at least one wear-resistant PVD surface layer is applied, which contains titanium nitride, titanium carbonitride, titanium aluminonitride, chromium nitride, tungsten carbide/carbon, or a diamond-like coating material.

8. A method as claimed in any of the claims 3 to 7, **characterized** in that the base material to be coated is unwound from a first reel and wound onto a second reel, while the coating takes place in the area between the reels.

9. A doctor blade or a coating blade for a paper/board or finishing machine, **characterized** in that the blade comprises a base material composed of hardened steel, high-speed steel, or of sintered hard metal, onto which base material a PVD coating has been applied.

10. A doctor blade or a coating blade as claimed in claim 9, **characterized** in that, between the base material and the PVD coating, there is a carrying layer, which has been prepared by means of electrolytic hard-chromium plating or auto-catalytically out of chemical nickel.

11. A water drain rib for the wire part or for the press section in a paper/board or finishing machine, **characterized** in that, onto a base material, which has been made of stainless steel or acid-proof stainless steel, a carrying layer has been prepared, which is an electrolytic or auto-catalytic coating, and onto the carrying layer a PVD coating has been applied.

12. An applicator bar for a paper/board or finishing machine, **characterized** in that, on a base material made of stainless steel, there is a carrying layer which has been prepared electrolytically by hard-chromium plating or auto-catalytically, and on said carrying layer there is a PVD coating.

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 99/00316

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C23C 14/06, D21F 1/48, D21G 3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C23C, D21F, D21G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPIL, EDOC, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9741299 A1 (BTG ECLEPENS S.A.), 6 November 1997 (06.11.97), page 3, line 28 - page 4, line 15, claims 5-7,9-11	1-14
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X	DE 4123326 A1 (HORST SPRENGER GMBH), 21 January 1993 (21.01.93), column 1, line 1 - line 68; column 2, line 32 - line 49, figure 1, abstract	1-10,13,14
A		11,12
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 June 1999	07-07-1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Ingrid Grundfelt/ELY Telephone No. +46 8 782 25 00

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